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ORIGINAL ARTICLE

Abundance, habitat and body measurements of the rare Long-clawed Mouse (*Pearsonomys annectens*) in the coastal temperate rainforest of southern Chile

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Based on rodent trappings in eight localities from 1998 to 2005 (14,984 trap-nights), we provide detailed information on abundance, habitat and additional body measurements of the Long-clawed Mouse (*Pearsonomys annectens*), a rare rodent in the Valdivian temperate rainforest. The Long-clawed Mouse was collected in three localities only in both highly fragmented and continuous forests, including forestry plantations. The sites had relatively mature and closed vegetation and deep soils covered with leaf litter. Males appeared to be larger and heavier than females. Sexually active individuals were found in spring. We conclude that small and geographically restricted populations, low population densities, microhabitat specialization, and dependence on southern temperate forest make long-clawed mice vulnerable to the disappearance of the forest.

Keywords: Long-clawed Mouse; rarity; human-modified habitat; southern temperate rainforest; pine plantations

Introduction

The temperate rainforest of southern South America is characterized mainly by high plant biomass productivity, unusual diversity of vines and epiphytes, high richness of evergreen plants, high proportion of mutualistic plant–animal interactions, and high level of faunal endemism (Armesto et al. 1995). Although the small mammal community of the southern temperate rainforest is not highly diverse, it is highly endemic (Mella et al. 2002; Iriarte 2008). The endemism level of small mammals is comparable to ancient or insular faunas, suggesting that this forest has been an important scene of evolutionary processes, intervening probably strong climatic, vegetational and tectonic changes (Moritz et al. 2000). The Chilean mammals are thought to be the best known in South America (Pine 1982). However, after Pine (1982) new rodent species (e.g., Patterson 1992; Kelt & Gallardo 1994) and new distribution records of the less studied small mammals have been documented (e.g., Yañez et al. 1987; Kelt & Martínez 1989; Palma 1995; Saavedra & Simonetti 2000, 2001; Lobos et al. 2005). Nonetheless, recent assessments focused on knowing the diversity and distribution of the coastal native flora and fauna in southern Chile have not included small mammals (e.g., Smith-Ramírez et al. 2007).

The Long-clawed Mouse (*Pearsonomys annectens*) is the most recently discovered rodent species in the Valdivian temperate rainforest (Patterson 1992). It belongs to the tribe Abrothrichini (Muridae: Sigmodontinae; D'Elía et al. 2007) and together with the genera *Notiomys*, *Chelemys* and *Geoxus* constitutes the long-clawed mice group (Patterson 1992). The Long-clawed Mouse is a small rodent (ca. 200 mm in total length) characterized mainly by its uniformly dark fur, long forefeet claws and long tail (70–80 mm; see Fig. S1, Supplementary Online Material). This latter characteristic distinguishes it from other long-clawed mice (Patterson 1992). Even though the species has been described as fossorial and herbivorous-insectivorous (Iriarte 2008), its fossoriality is not clear at all and its diet is virtually unknown (Patterson 1992, Iriarte 2008, Rodríguez-Serrano et al. 2008).

Distribution of the Long-clawed Mouse was only known for a very small portion of the coastal range of southern Chile including the localities of Mehuín and San Martín (39°26′–39°30′ S, 73°07′–73°10′ W; Patterson 1992; Smith & Patton 1999). Recently, based on specimens we captured in the field, D'Elía et al. (2006) extended the southern and northern distribution range of this rodent species. At present, the range of the Long-clawed Mouse extends from Comuy (Cautín Province) to Bahía San Pedro (40°54′ S, 73°53′ W) encompassing almost 220 km along the Chilean coastal range. Here we provide more detailed information on the abundance, habitat and additional

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body measurements of the Long-clawed Mouse, and discuss the implications for conservation.

Materials and methods

Study sites

As part of a series of studies to determine the distribution and abundance of rodents in the coastal mountain range, from 1998 to 2005 we carried out live trappings in several localities encompassing a line-transect of almost 400 km. From north to south, the localities were Comuy (39°02′ S, 72°58′ W; 92 km north of Valdivia), San Martín Experimental Forest (39°30′ S, 73°11′ W, 21 km north of Valdivia), Curiñanco (39°41′ S, 73°22′ W; 20 km northwest of Valdivia), Isla del Rey (39°53′ S, 73°19′ W; 12 km west of Valdivia), Alerce Costero Natural Monument (40°10′ S, 73°27′ W; 40 km south of Valdivia), Maicolpué (40°36′ S, 73°44′ W; 96 km south of Valdivia), San Pedro Bay (40°54′ S, 73°53′ W; 132 km south of Valdivia), and Cucao National Park, Chiloé (42°38′ S, 73°53′ W; 315 km south of Valdivia. Ecological conditions and topographic and vegetational characteristics of each locality are summarized in Table 1.

In Comuy the rodent trappings were carried out in an extensive commercial pine (*Pinus radiata*, Pinaceae) plantation (ca. 2000 ha) with small remnants of native forest covering ravines and road borders. Some Valdivian shrub species (e.g., *Aristotelia chilensis* Elaeocarpaceae, *Fuchsia magellanica* Onagraceae, *Amomyrtus meli* Myrtaceae) interspersed with non-native shrub species such as *Rubus ulmifolius* and *Rosa moschata* (Rosaceae) constituted the 'midstory' of the interior of the pine stands. In San Martin the trappings were made in an 80 ha area covered by multilayered old- and second-growth forests dominated by *Aextoxicom punctatum* (Aextoxicaceae) and *Podocarpus saligna* (Podocarpaceae) with scattered old individuals of emergent *Nothofagus dombeyi* (Fagaceae). The understory was sparse and composed mainly of saplings of *A. punctatum*, *P. saligna* and *Luma apiculata* (Myrtaceae). The trapping area in Curiñanco included a multilayered old-growth forest remnant of *A. punctatum*, a second-growth forest remnant of Myrtaceae, patches of growing forest, dense shrub patches, and a rush (*Juncus* spp. Juncaceae) marsh. The midstory in the *A. punctatum* forest was composed of scattered or densely distributed shrubs including *Myrceugenia planipes* (Myrtaceae), *Eucryphia cordifolia* (Eucryphiaceae), *Drymis winteri* (Winteraceae), *L. apiculata* and *A. meli*. The myrtacean forest was composed mainly of *A. meli*, *L. apiculata*, and *M. planipes*. Growing forests were constituted mainly by *A. punctatum*, *D. winteri*, *E. cordifolia*, *A. chilensis*, *Laureliopsis philippiana* (Monimiaceae), *Rhaphithamnus spinosus* (Verbenaceae), and *Embothrium coccineum* (Proteaceae). Shrub patches were composed of *Pernettya mucronata* (Ericaceae) and *Ugni molinae* (Myrtaceae). Trappings in Isla del Rey were made in shrub patches composed of both native (e.g., *A. chilensis*, *F. magellanica*) and introduced species (e.g., *R. ulmifolius*). The trapping area in the Alerce Costero Monument comprised an extensive old-growth Alerce (*Fitzroya cupressoides*) forest with a midstory composed of *Tepualia stipularis* (Myrtaceae) and *Desfontainia spinosa* (Loganiaceae). In Maicolpué the trappings were made in growing forest and shrub patches very similar to those present in Curiñanco. The trapping area in San Pedro Bay was a mosaic of dense native shrub patches, small and highly degraded forest remnants, and open areas covered by pastures. Shrub patches were dominated by *U. molinae* and covered > 65% of the trapping area. Forest remnants were composed mainly of *A. luma*, *D. winteri*, *L. apiculata*, *A. meli* and some individuals of *A. punctatum*, *F. cupressoides*, and *Lomatia ferruginea* (Proteaceae). The ground in open areas was partially covered by non-native herbs such as *Holcus lanatus*, *Agrostis* spp. (Poaceae), *Acaena ovalifolia* (Rosaceae), *Plantago lanceolata* (Plantaginaceae) and *Nertera granadensis* (Rubiaceae). In the Cucao National Park the trappings were made in the ecotone between the old-growth *Nothofagus nitida* forest and the coastal shrub carpet, dominated by *U. molinae*.

Rodent sampling

For each locality we established a variable number of trap lines (Table 2) using medium-sized (24 × 9.4 × 7.5 cm) Sherman live traps 4–10 m apart. Traps were not uniformly spread out mainly because of topographic and habitat restrictions. All traps were baited with rolled oats. Relative abundance for each rodent species was calculated by two methods: trapping success (number of captured individuals/number of trap-nights) and frequency (number of captured individuals/total number of captured individuals from all species). At the sites where we recorded long-clawed mice we measured qualitative variables of the habitat including vegetation type, dominant plant species, successional stage, compass orientation of slopes, slope (in °), elevation (in m), relative stage age (in years), canopy cover for forests (in %), carpet cover for shrubs (in %), maximum canopy height (forests) or carpet height (shrubs; in m), mean tree diameter at breast height (dbh in cm), and mean number of snags/ha. Measurements were made in a trapping area of almost 2 ha. All trapped animals were measured, weighed

Table 1. Vegetational and physiognomic features, and human uses of the localities where rodent trappings were carried out throughout the Coastal mountain range of southern Chile.

Characteristics	Comuy	San Martin Reserve	Curiñanco	Isla del Rey	Coastal Alerce Monument	Maicolpué	San Pedro Bay	Cucao National Park
Dominant terrain form	Rugged	Flat-rolled	Mountainous, rugged	Rugged	Rugged	Mountainous	Mountainous, rugged	Rugged
Elevations (m)	45–326	10–20	2–300	10–320	200–1000	12–245	10–560	12–560
Slopes (°)	10–30	1–10	10–40	10–30	5–50	15–35	20–45	10–35
Slope orientation	E	SE	W	W	E	W	W	W
Distance to coastline (km)	25	14	0.2	3	19	0.5	0.3	1
Land uses	Forestry, agriculture, livestock, human habitations	Agriculture, protection	Human habitations, livestock	Forestry, human habitations	Protection	Tourism, livestock	Livestock, human habitations	Protection
Actual dominant plant cover	Pine plantation	Forest, shrubland	Forest	Pine plantation, shrubland	Forest	Forest, shrubland	Forest, shrubland	Forest
Original forest type	Evergreen forest/mixed-deciduous *Nothofagus* forest	Evergreen forest/mixed-deciduous *Nothofagus* forest	Evergreen forest	Evergreen forest	Alerce (*Fitzroya cupressoides*) forest	Evergreen forest	Evergreen forest	Evergreen forest
Forest seral stage	Second-growth	Old-growth	Second-growth	Second-growth	Old-growth	Second-growth	Second-growth	Second-growth
Forest history	Conversion to agricultural land, fires, substitution of native forest by forestry plantations	Conversion to agricultural land, fires	Fires	Fires, substitution of native forest by forestry plantations	Protection, fires	Fires	Logging, conversion to agricultural land	Logging, conversion to agricultural land
Forest management	Firewood	Preservation, firewood	Firewood	Firewood	Preservation	Firewood	Firewood	Preservation
Level of human presence	High	Low	Low	Medium	Low	High	High	Medium

Table 2. Design of rodent trapping in the coastal mountain range of southern Chile.

Design	Comuy	San Martín Reserve	Curiñanco	Isla del Rey	Coastal Alerce Monument	Maicolpué	San Pedro Bay	Cucao National Park
Seasons and years	Sp 2003 Wi 2004 Su 2005 Wi 2005 —	Wi, Sp 1998 Su, Au, Wi, Sp 1999 Su, Au, Wi 2000 Su, Au, Wi, Sp 2001 —	Su 1999 Wi, Sp 2001 — —	Au, Wi 2000 — — — —	Wi 98 — — — —	Su 1999 — — — —	Au 1998 Sp 2000 Au, Sp 2001 Sp 2004 Au 2005	Su 1999 — — — —
No. of samplings per season	1	1–2	1	1	1	1	1	1
No. trap lines per sampling	36	10	11, 12, 15‡	4	14	8	14	4
No. traps per trap line	8	8	10	18	12	18	11	40
No. nights of trapping per season	3–4	3–7	2, 4, 4‡	2, 4‡	5	2	3–5	1
No. total nights of trapping	14	65	10	6	5	2	22	1
No. trap nights†	3689	5199	1241	389	821	277	3215	153

†Non-functional traps were discounted.
‡Number of trap lines and nights of trapping are correlative to each season given above.

and sexed. Sexually active individuals were identified by the presence of scrotal testes or open vagina, and sexually inactive individuals were recognized by the presence of abdominal testes or closed vagina. All specimens were released live at the capture site and those found dead in traps were prepared for furs and deposited in the mammal collection of the Austral University in Valdivia.

Results

Trapping success and relative abundance

Overall, the trapping success for each rodent species was low (< 5%, Table 3). Among all captured rodents, *Abrothrix longipilis*, *A. olivaceus* and *Oligoryzomys longicaudatus* were the most numerous species (Table 3). *Pearsonomys annectens* was found in three localities only (Comuy, San Martín and San Pedro) accounting for less than 2% of captured rodents at those sites (Table 3). Another similarly rare species was *Geoxus valdivianus*. In total, long-clawed mice accounted for only less than 1% of captured rodents across all sites.

Habitat characteristics

Long-clawed mice were collected both in highly fragmented and continuous forest landscapes (Figure 1). Localities with presence of long-clawed mice differed strongly in vegetational and topographic features and land use (Table 1, Figure 2). In Comuy, we captured specimens in a small area of mature pine (ca. 5 ha). The midstory in the capture site was relatively dense and the floor was covered by a deep layer of needles. In addition, the capture site was very close to a small forest remnant covering a small ravine (Figure 2A). In the San Martín Forest, *P. annectens* was captured in sites where the midstory was sparse and the soil was covered with a thick layer of mosses and leaf litter. In San Pedro we found one individual in the interior of a very dense patch of *U. molinae* (ca. 0.8 ha). Although most variables did differ among localities, all sites with Long-clawed Mouse were covered with relatively mature and closed vegetation (Table 4).

Body measurements and breeding status

An equal number of male and female long-clawed mice were captured during our trappings (Table 5). According to mass and total length, males appeared to be larger than females.

Table 3. Trapping success (S%) and frequency (N%) of rodent species in the coastal mountain range of southern Chile. S% = (number of captured individuals of each species/number of trap-nights) × 100. N% = (number of captured individuals of each species/total number of captured individuals) × 100.

	Comuy		San Martín Reserve		Curiñanco		Isla del Rey		Coastal Alerce Natural Monument		Maicolpué		San Pedro Bay		Cucao National Park		Total	
Species	S%	N%	S%	N%	S%	N%	S%	N%	S%	N%	S%	N%	S%	N%	S%	N%	S%	N%
Abrothrix longipilis	2.5	68.9	1	14.3	0.2	2.1	1	16	3.8	56.3	—	—	4	31.6	1.3	3.5	2.1	26.1
Abrothrix olivaceus	0.6	15.6	4	56.5	4.4	38.4	4.1	64	1.3	20	2.5	38.9	3.7	29.1	22.9	60.3	3.1	38.9
Geoxus valdivianus	—	—	< 0.1	0.8	—	—	—	—	0.1	1.8	—	—	—	—	—	—	< 0.1	0.3
Irenomys tarsalis	0.1	2.2	—	—	—	—	—	—	0.4	5.5	—	—	—	—	—	—	< 0.1	0.5
Loxodontomys micropus	—	—	< 0.1	0.3	—	—	—	—	—	—	—	—	0.2	1.2	—	—	< 0.1	0.5
Oligoryzomys longicaudatus	0.4	11.1	1.6	22.9	4.8	42.0	0.8	12	1.1	16.4	1.8	27.8	4.7	36.4	13.1	34.5	2.3	28.5
Pearsonomys annectens	< 0.1	1.5	0.1	1.4	—	—	—	—	—	—	—	—	< 0.1	0.2	—	—	< 0.1	0.7
Rattus rattus	—	—	0.3	3.8	0.8	7	0.3	4	—	—	2.2	33.3	0.2	1.5	—	—	0.2	3
Rattus norvegicus	< 0.1	0.7	—	—	1.2	10.5	0.3	4	—	—	—	—	—	—	0.7	1.7	0.1	1.5
Total no. of species	6		7		5		5		5		3		6		4		9	
Total no. of individuals	135		363		143		25		55		18		412		58		1209	
Total trap nights	3689		5199		1241		389		821		277		3215		153		14984	
Overall trapping success	3.7		7.0		11.5		6.4		6.7		6.5		12.8		38		8.1	

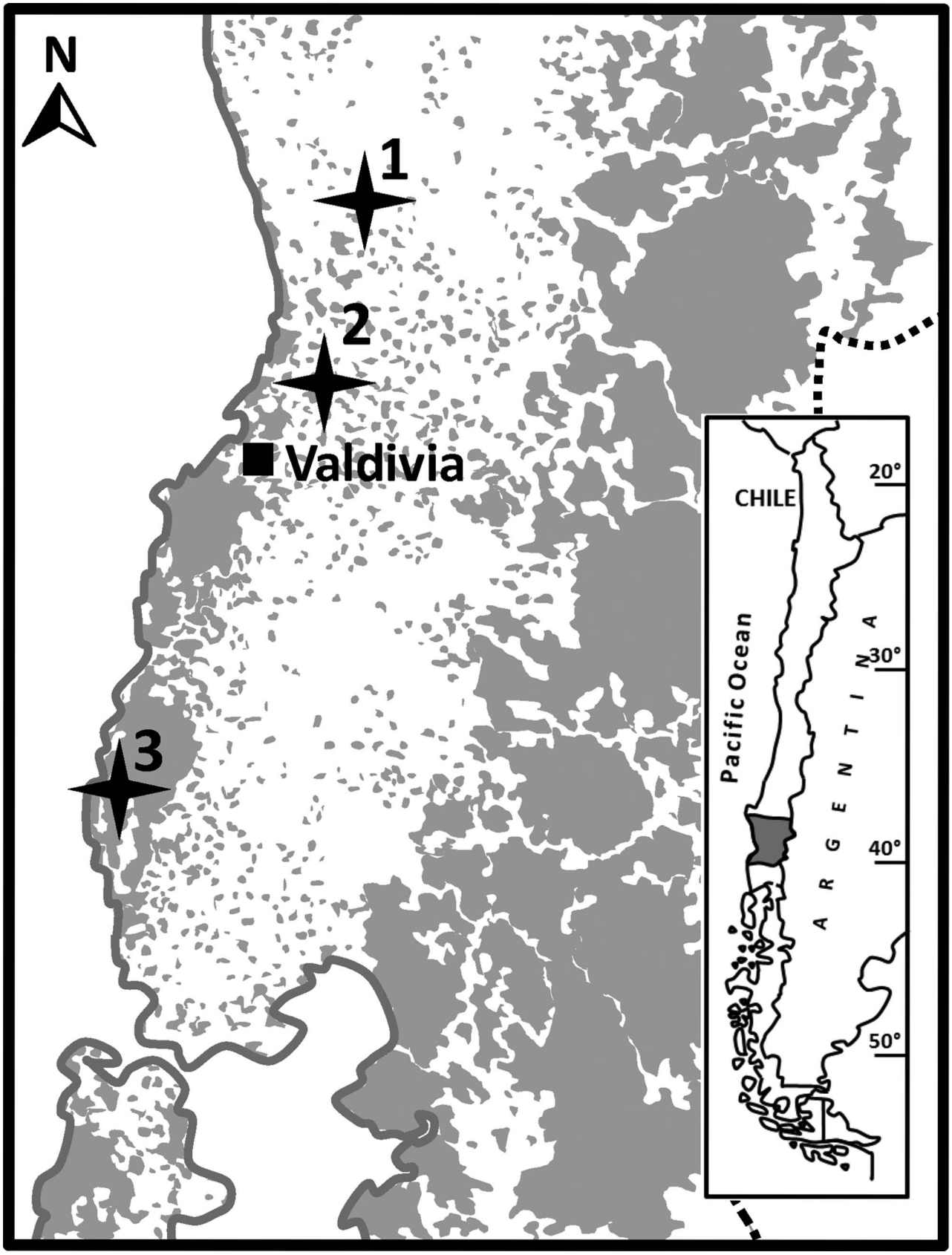
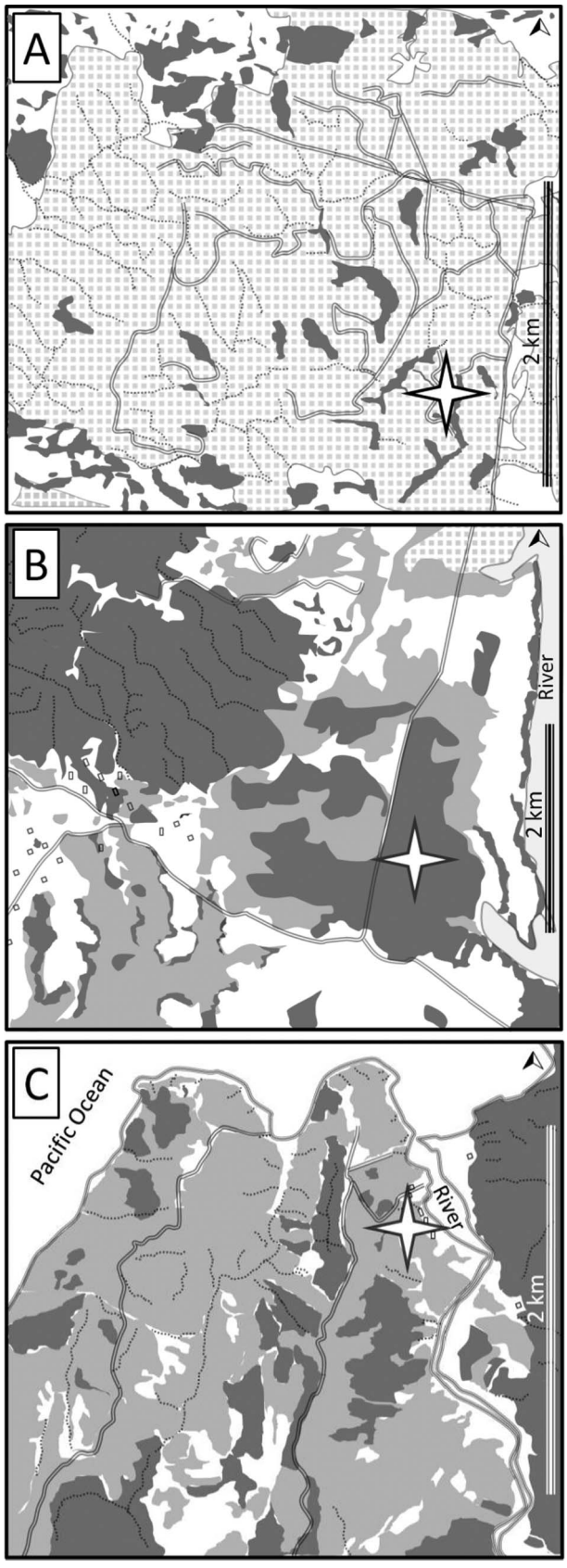


Figure 1. Localities where long-clawed mice (*Pearsonomys annectens*) were captured in the coastal range of southern Chile. 1 = Comuy, 2 = San Martín Reserve, 3 = San Pedro Bay. Gray: current extension of native forest, white areas: non-forested land including farmland, urban areas and areas above the treeline.



Discussion

Rarity of the Long-clawed Mouse

As supposed by Patterson (1992), the Long-clawed Mouse appears to be extremely rare. However, its rarity could also be an artifact of the trapping method because Sherman traps seem to be more selective with cursorial (e.g., *Abrothrix* spp.) than with arboreal (e.g., *Irenomys tarsalis*, *Dromiciops gliroides*) and/or fossorial (e.g., *Geoxus valdivianus*, *P. annectens*) small mammals (Rau et al. 1995; Quijano 2008; Fontúrbel & Jiménez 2009). The use of pitfall traps in subsequent studies could help to elucidate this uncertainty. Because native predators may capture a different spectrum of rodent species and with different frequencies than do the traps (Bonvicino & Bezerra 2003), owl pellets and carnivore scats could also be used to detect the presence of the Long-clawed Mouse. Up to now, however, predation on long-clawed mice by owls, foxes or puma has not been recorded in coastal areas (Rau et al. 1985; Martínez 1993; Martínez et al. 1993; Martínez & Jaksic 1997; Rau & Jiménez 2002). Conversely, the sympatric *G. valdivianus*, being more specialized for fossorial life (Mann 1978; Patterson 1992), has commonly been found in owl pellets and carnivore scats (Martínez 1993; Rau et al. 1995; Martínez & Jaksic 1997; Jiménez 2008). This may be a result of distinct life modes or the extreme rarity of Long-clawed Mouse.

Presence of long-clawed mice in human-modified habitats

Based on specimens from Mehuin and San Martín, Patterson (1992) indicated that long-clawed mice inhabit southern beech (*Nothofagus* spp.) forest remnants with southern bamboo (*Chusquea* spp.) and Valdivian temperate rainforest remnants. In addition, Patterson (1992) presumed that the range of the species would include the coastal elevation and, at least formerly, the adjacent lowlands; a presumption that was corroborated by our study. According

Figure 2. Vegetational and topographic features and land with human use around sites where long-clawed mice (*Pearsonomys annectens*) were captured (stars) in the coastal mountain range of southern Chile. A = Comuy, B = San Martín Reserve, C = San Pedro Bay. Dark gray: native forest (old-growth or second-growth remnants), light gray: native shrub, gray squares: forestry plantations (*Pinus radiata*), white: agricultural land or deforested areas, dotted lines: ravines, and parallel lines: roads. Small squares or rectangles represent human residences. Arrowhead indicates north.

Table 4. Habitat features of sites where Long-clawed mice (*Pearsonomys annectens*) were captured in the coastal mountain range of southern Chile.

Variables	Localities		
	Comuy	San Martín reserve	San Pedro Bay
Vegetation type	Pine plantation	Forest	Shrub
Dominant plant species	*Pinus radiata*	*Aetoxicom punctatum*	*Ugni molinae*
Seral stage	Mature	Old-growth	Mature
Compass orientation of slopes	SW	NW	NE
Slope (°)	15	5	40
Elevation (m)	214	10	40
Relative stage age (years)	20	250	30
Canopy cover (%)	70–80	65–80	—
Carpet cover (%)	—	—	90–95
Maximum canopy height (m)	20	35	—
Maximum carpet height (m)	—	—	1.5
Mean tree dbh (cm)	35	51	—
Mean number of snags/ha	0	19	0

Table 5. Body measurements, sex and breeding status of long-clawed mice (*Pearsonomys annectens*) captured from 1999–2005 in the coastal mountain range of southern Chile. Sex: F = female, M = male; breeding status: CV = closed vagina, OV = open vagina, AT = abdominal testes, ST = scrotal testes.

			Length (mm)					
Locality	Season*	Mass (g)	Total	Tail	Ear	Foot	Sex	Breeding status
Comuy†	Sp 2003	42	190	78	18	25	F	CV
	Wi 2005	47	192	71	18	25	M	AT
San Martín reserve	Wi 1998	55	201	85	18	25	M	AT
	Au 1999	20	161	68	15	24	F	CV
	Su 2001	24	180	76	17	27	F	—‡
	Sp 2001	53	207	80	17	25	M	AT
	Sp 2001	47	202	82	18	25	F	OV
San Pedro Bay†	Sp 2001	48	208	82	19	26	M	ST

*Sp = spring, Su = summer, Au = autumn, Wi = winter.
†Measurements from our specimens were previously reported by D'Elía et al. (2006).
‡Not registered.

to the first habitat descriptions, it would have been expected that long-clawed mice were only found in scarcely human-modified habitats. However, one of our major finding was that long-clawed mice inhabited sites highly modified by humans (Figure 2). This could possibly be explained by a high tolerance to human activities, fidelity to reproductive sites or large or stable food resources. Some habitat-specialist species may persist in a site to the extent that the changed habitat permits survival and reproduction, even at below replacement rates ('the ghost of the past habitat', Knick & Rotenberry 2000). In the particular case of forestry plantations, persistence of long-clawed mice would be facilitated by the presence of native vegetation under the canopy which could provide refuge, prey, habitat corridors and source of recolonization (e.g., Estades & Temple 1999, Briones & Jerez 2007). In addition, although not evaluated by us, the ground where we captured long-clawed mice was soft and apparently deep. This habitat condition could facilitate foraging for prey because most invertebrate species inhabiting the underground tend to stay in sites with deep soil despite macrohabitat modifications (Saavedra & Simonetti 2001). In sum, it is possible that the presence of closed vegetation (forest, plantation or shrub) and soil conditions are key features for the occurrence of long-clawed mice at a particular site. Finally, we would like to emphasize that the presence of specimens in human-modified habitats could be circumstantial and more studies are needed to confirm such pattern in habitat use.

Body measurements and breeding status

Our measurements suggest a sex difference in the body size of the Long-clawed Mouse with males tending to be larger than the females. However, it is possible that those lighter and smaller females were

juvenile animals. The finding of some sexually active individuals in the spring suggests that the breeding cycle initiates during this season.

Implications for conservation

Even though the actual knowledge on distribution ranges of endemic forest-specialist small mammals might not be definitive (Kelt & Martínez 1989; Saavedra & Simonetti 2000, 2001; Lobos et al. 2005; Kelt et al. 2008), it is clear that their continuity has been negatively affected by the extensive loss of native forests (Fuentes 1994; Smith-Ramírez 2004; Echeverría et al. 2006). The scarce information about its natural history and ecology make it difficult to assess the conservation status of *P. annectens*, but its fossoriality, whatever its degree, could make it vulnerable to predation by domestic predators near human settlements. Dogs and pigs may easily dig up and capture fossorial or epigeous fauna. In addition, soils of the southern coastal range are susceptible to degradation due to their soft composition (e.g., clay, sand, volcanic ash), steep terrains, and exposure to landslides (Gayoso & Iroumé 1991) putting at risk those sites occupied by long-clawed mice where there are forest fires and logging. Following Primack et al. (2001), we presume that at least four characteristics of the Long-clawed Mouse would make it vulnerable to the disappearance of the forest: (1) small, geographically restricted populations; (2) low population densities; (3) microhabitat specialization inhabiting unstable grounds; and (4) dependence on southern temperate rainforest.

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